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THESIS

NAVY OFFICER MANPOWER OPTIMIZATION INCORPORATING BUDGETARY CONSTRAINTS

by

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March 2009

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13. ABSTRACT (maximum 200 words)

Every two years, the Chief of Naval Operations is responsible for submitting the Program Objectives Memorandum to the Secretary of the Navy for further review and inclusion in the President's two-year budget input to Congress. The Chief of Naval Personnel's Strategic Resourcing Branch is challenged with building a manpower budget program that both meets the budget limitations set forth by Congress and the manning requirement choices made by Navy leadership. This thesis develops the Requirements-Driven Cost-Based Manpower Optimization (RCMOP) model. RCMOP is a linear optimization program designed to guide monthly values for officer inventory, promotions, accessions, designator transfers, and forced and natural losses. RCMOP's goal consists of minimizing a weighted penalty function of unmet manpower requirements while meeting the Navy's fiscal constraints over a two-year time horizon. Implementation of the test scenario shows that resulting costs fall within 10% of predicted budget estimates, and promotion metrics approximate the values expected by law and policy. The model also indicates a need to increase total OCS accessions (by 11%) with respected to projected values as well as the percentage of 1000-coded billets filled by staff and fleet support officers.

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NAVY OFFICER MANPOWER OPTIMIZATION INCORPORATING BUDGETARY CONSTRAINTS

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ABSTRACT

Every two years, the Chief of Naval Operations is responsible for submitting the Program Objectives Memorandum to the Secretary of the Navy for further review and inclusion in the President's two-year budget input to Congress. The Chief of Naval Personnel's Strategic Resourcing Branch is challenged with building a manpower budget program that both meets the budget limitations set forth by Congress and the manning requirement choices made by Navy leadership. This thesis develops the Requirements-Driven Cost-Based Manpower Optimization (RCMOP) model. RCMOP is a linear optimization program designed to guide monthly values for officer inventory, promotions, accessions, designator transfers, and forced and natural losses. RCMOP's goal consists of minimizing a weighted penalty function of unmet manpower requirements while meeting the Navy's fiscal constraints over a two-year time horizon. Implementation of the test scenario shows that resulting costs fall within 10% of predicted budget estimates, and promotion metrics approximate the values expected by law and policy. The model also indicates a need to increase total OCS accessions (by 11%) with respected to projected values as well as the percentage of 1000-coded billets filled by staff and fleet support officers.

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LIST OF ACRONYMS AND ABBREVIATIONS

AVIAT	Naval Flight Officers and Pilots (Aviation Community)
BAH	Basic Allowance for Housing
BAS	Basic Allowance for Subsistence
BSO	Budget Submission Office
CNO	Chief of Naval Operations
CNP	Chief of Naval Personnel
CWO	Chief Warrant Officer
FICA	Federal Insurance Contributions Act
FY	Fiscal Year
HYT	High-Year Tenure
jSWO … jOTHER	Job requirements (billets) filled by SWO … OTHER communities
j1000	Job requirements (billets) filled by any officer
MPT&E	Manpower, Personnel, Training & Education
N1	Chief of Naval Personnel
NAVMAC	Naval Manpower Analysis Center
NCCA	Naval Center for Cost Analysis
NROTC	Naval Reserve Officer Training Corps
O-1 … O-6	Officer ranks: ENS, LTJG, LT, LCDR, CDR, CAPT, respectively
OCS	Officer Candidate School
OHA	Overseas Housing Allowance
OPIS	Officer Personnel Information System
OTHER	“Other” Designators Category
POM	Program Objective Memorandum
PR	Program Review
POE	Projected Operational Environment
RCMOP	Requirements-Driven Cost-Based Manpower Optimization
ROC	Required Operational Capability
SPEC	Special Operations/Special Warfare (Community)
SRB	Strategic Resourcing Branch
SUB	Submarines (Community)
SWO	Surface Warfare Officer (Community)
TFMMS	Total Force Manpower Management System
USN	United States Navy
USNA	United States Naval Academy
YCS	Years of Commissioned Service
YOS	Years of Active Service

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EXECUTIVE SUMMARY

Every two years, the Chief of Naval Operations is responsible for submitting the Program Objectives Memorandum (POM) to the Secretary of the Navy for further review and inclusion in the President's two-year budget input to Congress. The POM provides an eight year description of the Navy's planned spending, with the first two years being a detailed budget program and the next six as an estimate of future needs and a launch point for future POMs.

The Chief of Naval Personnel's (N1's) Strategic Resourcing Branch (N1-SRB) is responsible for programming the manpower budget by (a) analyzing the strength (manpower inventory) forecasts, and (b) estimating, as accurately as possible, the Navy's expenditures for the next eight years so they can be included in the budget and POM.

As each Navy Enterprise (Aviation, Surface Warfare, etc.) is competing for limited resources with which to maximize its manning, the N1-SRB must act as an honest broker in being a responsible steward of the Navy's budget. The challenge faced by the N1-SRB is to build a manpower budget program that both meets the budget limitations set forth by Congress and the manning requirement choices made by Navy leadership.

This thesis develops the Requirements-Driven Cost-Based Manpower Optimization (RCMOP) model. RCMOP is a linear optimization program designed to guide monthly values for officer inventory, promotions, accessions, designator transfers, and forced and natural losses. RCMOP's goal consists of minimizing a weighted penalty function of unmet manpower requirements while meeting the Navy's fiscal constraints over a two-year time horizon.

Our ultimate goal is to help the N1-SRB to develop an analysis tool that, when combined with other existing methods, can help planners to solve the complex budgetary and manpower problems they face.

This research devotes substantial effort to verify the model's solutions are credible (within the level of detail established in our modeling assumptions). Using a realistic test case as a "proof of concept" scenario, we suggest that an optimization model could be built with the appropriate level of detail to provide useful guidance to Navy manpower and budget planners.

Implementation of the test scenario shows that resulting costs fall within 10% of predicted budget estimates, and promotion metrics approximate the values expected by law and policy. The model also indicates a need to increase total OCS accessions (by 11%) with respected to projected values as well as the percentage of 1000-coded billets filled by staff and fleet support officers.

Recommendations for future improvements to RCMOP include enhancing the objective function's weighting scheme and structure, as well as including a comprehensive list of designators and subspecialty codes to fully specify the officer population and work requirements. In addition, we recommend interfacing the RCMOP with simulation models to better capture the inherent uncertainty in estimating loss rates and inflation.

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I. INTRODUCTION

Every two years, the Chief of Naval Operations (CNO) is responsible for submitting the Program Objectives Memorandum (POM) to the Secretary of the Navy (SECNAV) for further review and inclusion in the President's two-year budget input to Congress. The POM is published each even year and provides an eight year description of the Navy's planned spending, with the first two years being a detailed budget program, and the next six as an estimate of future needs and a launch point for future POMs (Defense Acquisition University 2004).

Military manpower expenditures accounted for more than $24 billion in the fiscal year 2007 (FY-07) budget, or around 20% of the Navy's spending. For FY-08 the planned spending decreased about 3%, but in FY-09 it is expected to increase back to the FY-07 levels (Table 1).

	FY-07 Actual	**FY-08 Planned**	**FY-09 Planned**
Pay and Allowances of Officers	6,228	6,200	6,442
Pay and Allowances of Enlisted	15,694	15,322	15,754
Pay and Allowances of Midshipmen	61	61	63
Subsistence of Enlisted Personnel	978	902	897
Permanent Change of Station Travel	809	723	791
Other Military Personnel Costs	277	111	135
Total: MPN	**$24,047**	**$23,319**	**$24,082**

Table 1. Military Personnel, Navy (MPN) appropriations table (millions of dollars). Actual or planned spending for Navy active duty personnel (Office of the Budget 2008).

The Chief of Naval Personnel's (CNP's/N1's) Strategic Resourcing Branch (N1-SRB) is responsible for programming the manpower budget by (a) analyzing the strength (manpower inventory) forecasts, and (b) estimating, as accurately as possible, the Navy's expenditures for the next eight years so they can be included in the budget and POM.

As each Navy Enterprise (Aviation, Surface Warfare, etc.) is competing for limited resources with which to maximize its manning, the N1-SRB must act as an honest broker in being a responsible steward of the Navy's budget. In addition, if insufficient funds exist to pay for manpower needs during the budget year of execution, then dollars will need to be shifted from other Navy accounts, such as procurement, to pay for the shortfalls. Table 2 shows expected Department of the Navy (DON) expenditures for FY-09.

	FY-09	**%**
Military Personnel	$41.60	28%
Procurement	$41.10	28%
Operations and Maintenance	$42.30	28%
Research and Development	$19.30	13%
MILCON	$4.90	3%
Total DON Budget	**$149.30**	

Table 2. Summary of Department of the Navy planned expenditures for FY-09 (billions). Right column shows the values as a percent of the total $149.3 billion budget. Values include active and reserve forces for the Navy and Marine Corps (Director, Navy Office of Budget 2008).

The challenge faced by the N1-SRB is to build a manpower budget program that both meets the budget limitations set forth by Congress and the manning requirement choices made by Navy leadership. These requirements represent the real work it takes to run the Navy’s air, afloat and shore infrastructures. Unfortunately, years of funding cuts and the “do more with less” culture of today’s Navy have led to the acceptance that personnel inventories and billet authorizations will rarely match the requirements (CNO 2007).

The Navy’s Manpower, Personnel, Training and Education (MPT&E) Enterprise is led by the N1 and builds and executes plans with a stated mission to “anticipate Navy war-fighting needs, identify associated personnel capabilities, and recruit, develop, manage and deploy those capabilities in an agile, cost-effective manner (Hatch 2007).” Current initiatives within the MPT&E system seek to streamline the processes involved in translating the National Security, Military and Maritime Strategies into executable manpower programs. The CNO’s Guidance for 2008 states that:

> …we will determine the right type and levels of output required of our Navy, and align our resources and processes to deliver that output at the best cost. To this end, we must understand the return we derive from our investments of people, time, and money, and maximize them to the extent that effectiveness, efficiency and risk remain appropriately balanced. (Roughead 2007)

Supporting the CNO’s Guidance, this research is an exploration into the use of optimization to provide insights to Navy leadership on how best to allocate and program manpower resources.

A. PROBLEM STATEMENT

This thesis develops the Requirements-Driven Cost-Based Manpower Optimization (RCMOP) model. RCMOP is a linear optimization program designed to guide monthly values for officer inventory, promotions, accessions, designator transfers, and forced and natural losses. RCMOP's goal consists of minimizing a weighted penalty function of unmet manpower requirements while meeting the Navy's fiscal constraints over a two-year time horizon.

Specifically, the RCMOP concept is designed to address the following questions:

- Given budgetary and manpower constraints, can an optimization model be an effective tool to help the Navy allocate manpower resources to better meet work requirements?
- If so, then what officer manpower variables, such as accessions, promotions, designator transfers, forced losses, and billet fills (using inventory ranks one-up through one-down of requirement rank) can be leveraged to accomplish that task?

Our ultimate goal is to help the N1-SRB to develop an analysis tool that, when combined with other existing methods, can help planners to solve the complex budgetary and manpower problems described in this section.

B. THESIS OUTLINE

Chapter II gives a brief overview of current Navy manpower planning and programming practice, the budget programming process, and how RCMOP would fit into that process. We also review optimization-related literature in this topic. Chapter III presents the RCMOP model assumptions and its mathematical formulation. Chapter IV describes the implementation for a base-line scenario used to test functionality of the RCMOP's concept. Chapter V reports our conclusions and recommendations for future research.

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II. NAVY OFFICER MANPOWER AND BUDGET PROGRAMMING BASICS

The Navy, like other military branches, is split into officer and enlisted personnel, each of which has a unique structure with regard to strength levels, accessions, promotions, lateral movement between career fields, and losses. In this study we focus on the officer ranks as they are more predictable in terms of these structural features than the enlisted ranks.

This chapter summarizes how U.S. Navy (USN) planners manage challenges in manpower requirements, strength and budget constraints. The complexity of this problem stems partially from the variability of the unknowns with regard to the "human" aspect of forecasting the future behavior of sailors. The following descriptions come from the CNO's Instruction 1000.16K (CNO 2007), personal interviews with members of the N1-SRB staff, and a summary of laws, directives, policies and practices compiled and presented by CDR Hatch (2007).

A. OVERVIEW OF MANPOWER PLANNING

The Navy's manpower management system is built around three important elements that govern the allowable personnel inventory: (1) work requirements, which are the unconstrained manpower needs for each Navy enterprise; (2) authorizations, which are the requirements that a Navy Budget Submission Office (BSO, where the BSOs include each fleet, the personnel command, and the reserve forces, among others) has chosen to fund; and (3) end strength, which is the congressionally-mandated upper limit on the total officer and enlisted populations that the Navy can have at the end of a given fiscal year.

1. Work Requirements

The Navy's personnel work requirements are best described as the "spaces" needed to be filled in order to accomplish the Navy's wartime mission. The number and type of these "spaces" are found when the Navy's Resource Sponsors, including the Expeditionary, Surface, Submarine and Aviation Enterprises, convert the National Military Strategy, Required Operational Capabilities (ROC) and Projected Operational Environments (POE) into unbounded work requirements. The Naval Manpower Analysis Center (NAVMAC) determines the manning levels needed to fill these requirements by analyzing the ROCs and POEs to the detail of a watch station, required maintenance, and unit support level utilizing the Navy's Standard Workweek for both deployed and shore units. These requirements are written to the minimum skill, pay grade and quantity of personnel needed to accomplish all aspects of the defined scenarios as written in the ROC and POE. Unfortunately, these requirements usually field unrealistic manpower levels, given the financial and end-strength constraints imposed by congress.

2. Authorizations

Each Enterprise and Resource Sponsor within the Navy chooses which requirements they will fund, as the Navy's manpower budget historically only covers approximately 94%

of the NAVMAC determinations. Once these funds are assigned, the various BSOs can authorize payment for specific requirements by rank and specialty. A requirement does not become an authorized billet, however, unless it is supported by end strength.

3. End Strength

In addition to setting budgetary constraints, Congress also limits the total enlisted and officer personnel that can be on the inventory at the end of each FY. For example, end strength for FY-08 was 328,400 total active-duty personnel; on September 30, 2008 the USN could have no more than that number of uniformed personnel on active duty to carry over into FY-09.

4. Personnel Planning

As billets are authorized, accession and promotion planners must adjust the flow of personnel accordingly to meet authorizations and account for expected losses. Filling these billets is accomplished by recruiting new officers, training new and existing officers, and promoting officers (all in the appropriate number and type). New officer accessions come from the U.S. Naval Academy (USNA), the Naval Reserve Officer's Training Corps (NROTC), Officer Candidate School (OCS), or as a direct accession through Officer Indoctrination School.

5. Programming

Budget programming for manpower serves as the link between manpower planning and budget execution. The budget programming office works to determine the affordability of the manpower plans by comparing the planned authorizations to the available monetary resources. An executable solution for the current year plus a seven-year plan is published in the form of the POM during even years, or revised in the Program Review (PR) in odd years. These documents are submitted for review and inclusion in the President's Budget Submission.

6. Current Manpower and Budget Programming Practices

USN personnel planners use a variety of spreadsheet-based models, incorporating Markov-chain transition rates, to help forecast officer manpower levels. In addition, planners and decision-makers tend to avoid optimization models due "in part to the fact that users of such models may find solutions derived from the 'black box' of an optimization algorithm difficult to explain or modify" (Rodgers 1991).

In recent years, programming future expenditures has been done using various methods. For years, the budget program was created by applying inflation indices to the most recent year's expenditures. For example, last year's expenditures would be updated for expected inflation rates and force-size changes to predict current and out-year budget numbers. This method failed to capture the impact of specific force-shaping decisions, as well as how simultaneous changes to multiple manpower variables would impact actual costs. In an age where access to data is nearly limitless and databases contain far more detailed information about our personnel inventory, planners sought to devise better approaches.

A more recent programming methodology is the "Bottom-up Build", which looks at the current force and the future requirements established by the individual Enterprises. By factoring in the detailed costing terms associated with each member of the current inventory, this model approximates what the current force will cost in future years. This approach, however, only identifies shortfalls or excesses without the ability to find where slack or surplus must be added to find a "good, close-to-feasible solution." By a good and close-to-feasible solution we refer to a manpower plan spanning two or more years that meets budgetary constraints and reduces "infeasibility gaps" associated with unfunded requirements. Later in this document we will formally introduce a "gap" index which accounts for the greater importance of certain mission-critical fields.

B. RELATED LITERATURE

Significant work has been done in the field of military manpower optimization models over the past 30 years, especially for the U.S. Army and USN. While those presented in this section (and references therein) only scratch the surface of the amount of work that has been done in the area of manpower models, they provide an overview of significant contributions to military manpower optimization.

Grinold and Marshall (1977) provide a generalized look at optimization as a technique to use in manpower planning and how it compares with other operations research-based methods for building such models. Holz and Wroth (1980) discuss the history of the U.S. Army's use of linear programming for manpower planning purposes throughout the 1970s and discusses the improvements made to those models during the first ten years of their use. Gass (1991) summarizes the use of various modeling techniques, including network and Markovian models, with emphasis on their application in a military manpower setting.

Bres et al. (1980) theorize a goal-programming model to optimally plan Navy officer accessions to meet forecasted future strength requirements. Similar to the RCMOP, the authors combine the warfare designators into sub-groups for analysis purposes. In addition to the programmed goals of meeting manpower requirements for the various communities and experience levels, they also include budget limits for specific time periods (but never activate that component in the implemented example).

Morben (1989) considers the application of a Simulation-Optimization (SIMOP) model to determine a minimum-cost five-year solution to Nuclear-Trained Surface Warfare Officer accession planning. The model accounts for the source costs, salary, and accession capacities from the various on-ramps into the community. Morben's is the only prior work we are aware of that addresses the Navy's ability to detail an officer to a billet one rank above or below their current rank, known as the "one-up, one-down" rule. As in our model, the author assumes no prior-service sailors by equating years of commissioned service (YCS) with years of active service (YOS).

Rodgers (1991) uses a multi-objective linear program to recommend monthly inventories, strengths, advancements and recruiting goals for the Navy's enlisted force over a three year planning horizon. The model includes personnel cost calculations and budget constraints on a FY level aggregated over the entire enlisted population. The author does not, however, analyze force structure down to the community-level, nor allows for personnel to fill requirements with the "one-up, one-down" rule. In addition, no consideration is given to the "risk" associated with leaving certain requirements gapped, and the deviations from manpower targets are only described at the rank level.

Yamada (2000) develops an infinite-horizon model for U.S. Army manpower planning. Yamada uses convex quadratic programming to determine annual accessions, promotions, and separations in order to minimize the gaps between requirements and strength while meeting desired inventory targets. The model does not distinguish between O-1/O-2 officers, and combines forced and natural attrition into a single "programmed or managed loss" category. In addition, it uses a yearly time step by dividing the inventory into annual manpower snapshots. The model accounts for career field assignments (similar to the Navy's community assignments) upon promotion to Major, but does not account for transition between career fields after assignment.

Gibson (2007) develops an update to the Army's current officer manpower planning system by creating an annualized optimization model that matches manpower requirements and inventories at minimum cost, and highlights the variability in behavior across the officer population with respect to time-in-grade while complying with promotion and accession limits. While the model does not address budget constraints explicitly, it does use an estimated "annual investment" as a basis for the individual unit cost per officer. Also, it incorporates promotion zones based on the tracking of officer cohorts through time, using them to calculate promotion rates for use in promotion constraints.

C. THESIS OBJECTIVE

This research develops and implements the Requirements-Driven Cost-Based Manpower Optimization (RCMOP) model, and uses it to explore the utility of linear optimization as a tool for human capital planning.

A quantitative decision aid of this type could help budget and manpower planners to identify areas or periods where their projections may lead to deviations with the budget program or manpower plans. This in turn could help the Navy better forecast its human capital spending and improve consistency in the budget execution process.

As the author started his research in this problem, it became clear that the N1-SRB's expectation is not to have a finished product, but instead to explore analytical methods (based on formal optimization) with the potential to improve the current decision making process as it relates to the POM.

This research devotes substantial effort to verify the model's solutions are credible (within the level of detail established in our modeling assumptions). Using a realistic test case as a "proof of concept" scenario, we suggest that an optimization model could be built with the appropriate level of detail to provide useful guidance to Navy manpower and budget planners.

III. THE REQUIREMENTS-DRIVEN COST-BASED NAVY OFFICER MANPOWER OPTIMIZATION PROGRAM

In this chapter, we introduce the RCMOP linear optimization model. RCMOP seeks to minimize a “gap index” which measures how well a given structure of officer personnel compares with established manpower requirements over a two-year time horizon. It features a personnel balance-of-flow structure of officer populations as they move through time, rank and between designators. Additional constraints are designed to incorporate assumptions for budget, promotions, accessions, and losses. These prevent the direct use of network-flow theory to solve the problem. However, since computational run-time has not been an issue for the RCMOP instances we have tried, we have not pursued decomposition techniques that could exploit the partial network structure of the model.

In order to capture the granularity required for budgetary purposes, the model uses a monthly time step to input data and report variables. Deficit and surplus variables are used to identify where planned or limited values cause infeasibilities with respect to manpower requirements, which in turn determines our objective function.

In the remainder of this chapter, we describe the mathematical model and the assumptions made in its design.

A. PERSONNEL BALANCE-OF-FLOW ARCHITECTURE

Similar to how strength and inventory are tracked by Navy manpower planners, the RCMOP tracks officer inventory as a "snapshot" of personnel on the active duty list on the first day of each month. Then, data and variables are used to update inventory levels over the course of a given month (between the first and last days) to obtain the expected inventory for the first day of the following month. Figure 1 shows graphically how the population of a specific rank(r), YCS (y) and designator (d) would be carried forward from one month ($t-1$) to the next (t).

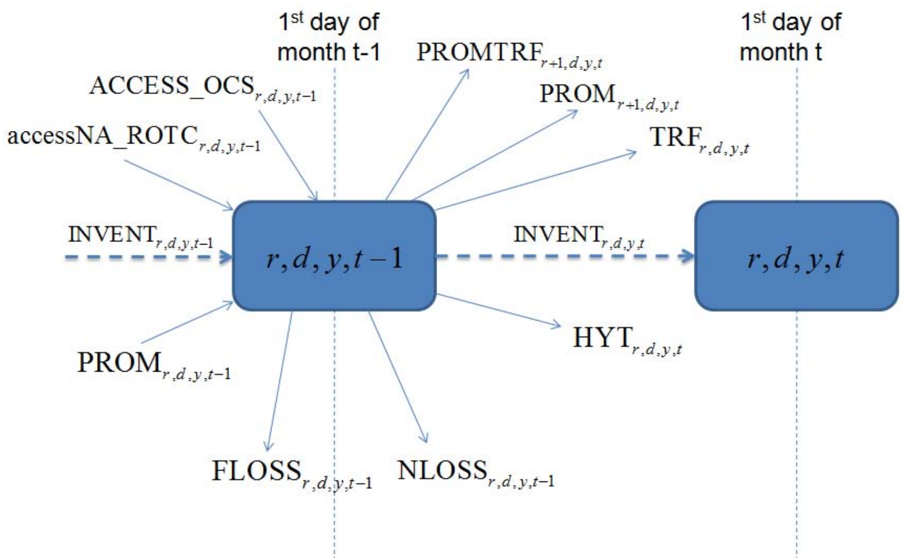

Figure 1. Balance of inventory flow. Case where d is not "OTHER," and t is not the first month or a YCS advancement month.

The *NLOSS* (natural loss), *FLOSS* (forced loss) and *HYT* (high-year tenure) terms represent strength losses to the Navy, while the *PROM* (promotion), *TRF* (transfer) and *PROMTRF* (promotion-transfer) terms refer to personnel exchanges between ranks and/or communities. The *accessNA_ROTC* and *ACCESS_OCS* terms represent the input of new officer accessions into the Navy. Remark: Figure 1 only describes the case where the designator is not "*OTHER*" and the YCS field is not advanced. Similar graphical depictions could be drawn for the other cases, as addressed in the model formulation below. All data and variable terms are described in-depth later in this chapter.

B. MODELING ASSUMPTIONS

As statistics pioneer George Box famously stated, "*all models are wrong, but some are useful*" (Box and Draper 1987). Some assumptions can greatly improve the simplicity of the model while only decreasing its accuracy slightly, and thus are worth the sacrifice. In this section, we detail and justify our assumptions and simplifications, as well as their anticipated impact on the solution.

1. Rank, Designator and Work Assumptions

For the purposes of the RCMOP, we limit the scope of the data and modeling capability by removing the flag and Chief Warrant Officer (CWO) ranks from consideration. In both cases, promotion timing and frequency are less regular and predictable than in the other ranks. In addition, the number of officers in each of those categories is relatively small compared to the Ensign (O-1) through Captain (O-6) ranks, so the model captures the majority of officers without the complications involved with modeling admirals and CWOs.

For similar reasons, we limit our scope of designator fields to those that follow more regular and predictable accession and promotion timelines. Specifically, we remove designators that bring in officers as new accessions at ranks other than O-1. These communities include Chaplain, Medical, Dental, Medical Service Corps, and Judge Advocate accessions (because they skip ranks). In most cases these communities are modeled independently of the rest of the officer corps due to their structural differences, and for that reason they are not included in this study. In addition, rather than individually modeling the dozens of designators that exist, RCMOP categorizes them into five subgroups: Surface Warfare Officer (SWO), Submarines (SUB), Special Operations/Special Warfare (SPEC), Naval Flight Officers and Pilots (AVIAT), and all others (OTHER).

Work Requirements	**Designator**
jSWO	SWO
jSUB	SUB
jSPEC	SPEC
jAVIAT	AVIAT
jOTHER	OTHER
j1000	SWO, SUB, SPEC, AVIAT, OTHER

Table 3. Summary of work requirement and designator categories.

Work requirements (Table 3) are divided into analogous “job” subcategories: SWO billets (jSWO), SUB billets (jSUB), SPEC billets (jSPEC), AVIAT billets (jAVIAT), general purpose billets (j1000), and all other billets (jOTHER). The j1000 category is the combination of 1000- and 1050-coded billets, and is assumed to be filled by any available officer. In reality, the 1050-coded billets can only be filled by any warfare-qualified officer (1050), but data limitations prevent us from adding that level of detail to the scenario tested using RCMOP.

2. Prior Service and Limited Duty Officers

The RCMOP model equates YCS with YOS for the purposes of calculating military pay, which is in actuality a function of both rank and longevity. For example, an officer of rank *LT* with four YCS and four YOS is paid less than a *LT* with four YCS and eight YOS. That is, officers who had active enlisted service prior to becoming commissioned officers are paid based on their enlisted and officer years and would have fewer YCS than YOS. Thus, by assuming all officers enter commissioned service with no years of active service, we fail to capture the prior-service element of the officer corps and underestimate their cost. The variability in community and YOS for these personnel makes this feature difficult to model, and thus is not incorporated in this thesis. Henceforth, and for the purposes of this research, YCS and YOS are used interchangeably.

Similarly, Limited Duty Officers (LDOs, who are exclusively prior-service personnel) are also removed from RCMOP.

3. Transferring between Designators

Naval officers have the ability to request a transfer from one designator to another, based on community needs and personnel availability. In most cases, officers in the more arduous and deployment-heavy fields are transferred to related staff designators, although it is possible to move between most of the warfare disciplines under certain circumstances. RCMOP prescribes the transferring needs for the communities, assuming they will be appropriately filled by community planners in execution. For simplicity, our modeling scenario allows officers to transfer from the warfare categories (SWO, SUB, SPEC, AVIAT) into the OTHER category, but not conversely.

4. Promotions and High-Year Tenure

Consistent with Navy policies and directives for promotion, RCMOP limits promotions to the YCS zones specified for a given rank. Table 4 shows the allowed ranges of YCS for promotion to a given rank (Secretary of the Navy 2006).

Rank	YCS	YCS for Promotion (to rank)	Promotion Rate (to rank)	YCS for HYT
O-6	21-29	21-23	40-60%	30
O-5	15-27	15-17	60-80%	28
O-4	9-19	9-11	70-90%	20
O-3	4-11	4	100%	12
O-2	2-3	2	100%	NA
O-1	0-1	NA	NA	NA

Table 4. Summary table of YCS, promotion and HYT values by rank. (SECNAVINST 1420.1B and U.S. Code, Title 10)

U.S. Code, Department of Defense (DoD) and Navy policies and directives also provide upper and lower bounds for the percentage of eligible officers that are promoted each year (Yardley et al., 2005). To give the RCMOP model greater flexibility, the promotion rate has been left unconstrained, creating a vacancy-based model where promotions are based on filling losses downstream rather than promoting based on specific required percentages. This allows us to compare "ideal" promotion rates (provided by RCMOP) with allowable values.

Law and policy also require that officers who fail to promote by certain career milestones are forced to leave after a certain number of YCS, called high-year tenure (HYT). Table 4 details the YCS values for which officers of a given rank are forced to leave active military service.

5. Losses

RCMOP losses are split into natural and forced losses. Natural losses are meant to capture the officers who voluntarily separate due to retirement (before HYT) or the end of service obligations, as well as uncontrollable losses due to medical or disciplinary reasons. These values are assumed to be a deterministic percentage of the current inventory. The calculation of these loss rates are described in detail in Chapter IV.1.

Forced losses, unlike natural losses, are meant to represent the Navy's controlled losses. For example, officer management can use involuntary separations or selective early retirement to either force or create incentives for personnel to leave active duty. For RCMOP purposes, the forced losses represent a decision variable indicative of ranks and designators that should consider removing excess personnel during given time periods.

6. Years of Commissioned Service

Each officer gains a YCS upon the anniversary of their commissioning each year. Because of the aggregated nature of our model and data, it would be difficult to capture each individual's actual month of commissioning to determine when in the modeling horizon we should increase their YCS. RCMOP advances the entire population each year on May 1, as this captures the majority of officers who enter commissioned service via the USNA and NROTC options and are commissioned during May. It is understood that the OCS graduates may not be accurately advanced in this case; however, errors on both sides (meaning early and late advancements) should approximately offset each other, although data to validate this claim is unavailable to the author.

7. Requirement Matching and Personnel Aggregation

For budgeting purposes, costing terms are applied to broad categories of personnel grouped by the same basic costs. RCMOP matches aggregated populations with total requirements for a given rank and designator. However, it does not take into account the complexity inherent to the detailing process on an individual level. For example, each officer is filling an individual billet and has an expected rotation date to determine their next duty station or possible departure date from active service. Neither is it likely that this date coincides with the member's promotion date, nor that a just-promoted officer moves immediately to a job coded for a higher rank upon being promoted. However, by having a large aggregated number of officers in the same rank and designator, and by limiting the one-up assignments to a percentage of the total, it is expected that the approximations RCMOP makes are acceptable.

C. MATHEMATICAL FORMULATION OF THE REQUIREMENTS-DRIVEN, COST-BASED MANPOWER OPTIMIZATION PROGRAM

In this section, we present the formulation for the RCMOP model.

1. Indices, Sets, Parameters and Variables

Indices

r Officer Ranks: *O1, O2, O3, O4, O5, O6*

d Designators: *SWO, SUB, AVIAT, SPEC, OTHER*

j Jobs: *jSWO, jSUB, jAVIAT, jSPEC, jOTHER, j1000*

y Years Commissioned Service: *y0,y1,…,y29,y30*

t Planning Month: *Oct08,Nov08,…,Aug10,Sep10,Oct10*

f Fiscal Year: *FY2009, FY2010, FY2011*

Sets

RY Subset of *(r,y)* pairs where it is possible that an officer with rank *r* has *y* YCS (see Table 4).

RY' Extended subset of *(r,y)* pairs including the next-to-feasible YCS *y* for rank *r*: $RY' = RY \cup \{(O1,y2),(O2,y4),(O3,y12),(O4,y20),(O5,y28),(O6,y30)\}$

RY^H — Subset of *(r,y)* pairs where an officer of rank *r* and YCS *y* reaches HYT (see Table 4).

RY^P — Subset of *(r,y)* pairs where officers can be promoted to the next rank *r* in YCS *y* (see Table 4).

RR^F — Subset of *(r,r') pairs* where officers of rank *r* can fill work requirements in rank *r'*, i.e.{ O1,O1 , O1,O2 , O2,O1 , O2,O2 , O2,O3 , O3,O2 , O3,O3 , O3,O4 , O4,O3 , O4,O4 , O4,O5 , O5,O4 , O5,O5 , O5,O6 , O6,O5 , O6,O6 }

DJ — Subset of *(d,j)* pairs where an officer in designator *d* can fill a requirement in job field *j* (see Table 3).

FT — Subset of *(f,t)* pairs where month *t* is in fiscal year *f*.

T' — Subset of months where YCS advancement occurs, i.e. *{May09, May10}*

Parameters [units]

$accessNA\_ROTC_{r,d,y,t}$ — The projected number of new officers accessed from USNA and NROTC sources into rank *r* and designator *d* with years of service *y* during month *t*. [persons]

$accessOCS_{r,d,y,t}$	The projected number of new officers accessed from OCS into rank r and designator d with years of service y during month t. [persons]
min_OCS, max_OCS	The minimum and maximum fraction, respectively, of the projected OCS accessions, used to bound OCS accessions as determined by RCMOP. [fraction]
$req_{r,j,t}$	The work requirement for officers of rank r and field j at the start of month t. [persons]
$budget_f$	Total dollars available to fund the model-specific officer manpower for the fiscal year f. [$]
$cost_{r,y,t}$	The monthly cost of an officer in rank r and YCS y at the start of month t. [$]
$\alpha_{d,y}$	The monthly loss factor for officers with designator d and YCS y. [fraction]
$invent0_{r,d,y}$	The initial inventory of officers present on the first day of the first month with rank r, designator d, and YSC y. [persons]
w_j	The weight (penalty) assigned to a shortfall within job field j. (Larger penalty is associated with greater importance to that work requirement.)

$\beta_{r,d}$ The minimum fraction of officers that must fill a same-rank work requirement with rank r and designator d. [fraction]

$\eta_{r,j}$ The maximum fraction of the total job requirement j and rank r that can be left unfilled. [fraction]

Derived Data

$\tilde{w}_{r,j,t}$ Normalized weight for job requirement j, rank r in month t. [fraction]. Defined as:

$$\tilde{w}_{r,j,t} = \frac{w_j req_{r,j,t}}{\sum_{r',j',t'} w_{j'} req_{r',j',t'}} \qquad \forall r, j, t \tag{1}$$

Variables [units]

$INVENT_{r,d,y,t}$ The number of officers present on the first day of month t with rank r, designator d, and YCS y. [persons]

$ACCESS\_OCS_{r,d,y,t}$ The number of new officers accessed from OCS into rank r and designator d with YCS y during month t. [persons]

$PROM_{r,d,y,t}$ The number of officers with designator d that are promoted into rank r, at the beginning of month t and with y YCS. [persons]

$TRF_{r,d,y,t}$ The number of officers with rank r that are transferred from designator d into designator "*OTHER*", at the beginning of month t and with y YCS. [persons]

$PROMTRF_{r,d,y,t}$ The number of officers that are promoted and transferred from designator d into rank r, designator "*OTHER*", at the beginning of month t and with y YCS. [persons]

$NLOSS_{r,d,y,t}$ The number of natural officer losses from rank r, designator d, and YCS y during month t. [persons]

$FLOSS_{r,d,y,t}$ The number of forced officer losses from rank r, designator d, and YCS y during month t. [persons]

$HYT_{r,d,y,t}$ The number of HYT officer losses from rank r, designator d, that would enter y YCS during month t. [persons]

$FILL_{r,r',d,j,t}$ The number of officers in designator d with rank r that fill a work requirement in job field j and rank r' at the start of month t. [persons]

$DEFICIT_{r,j,t}$ The shortage of officers needed to fill a given requirement in rank r and job field j at the beginning of month t. [persons]

$SURPLUS_{r,j,t}$ The excess of officers filling a given requirement in rank r and job field j at the beginning of month t. [persons]

2. Formulation

Objective Function:

$$\min \sum_{r,j,t} \tilde{w}_{r,j,t} \frac{DEFICIT_{r,j,t}}{req_{r,j,t}} \tag{2}$$

Subject to:

Inventory Initialization

$$INVENT_{r,d,y,\text{"}Oct08\text{"}} = invent0_{r,d,y} \qquad \forall r,d,y \mid (r,y) \in RY' \tag{3}$$

Flow Balance Equations

$$\begin{aligned} INVENT_{r,d,y,t} = {} & INVENT_{r,d,y,t-1} + PROM_{r,d,y,t} \\ & -PROM_{r+1,d,y,t} - PROMTRF_{r+1,d,y,t} \\ & -TRF_{r,d,y,t} - NLOSS_{r,d,y,t-1} \\ & -FLOSS_{r,d,y,t-1} - HYT_{r,d,y,t} \\ & +accessNA\_ROTC_{r,d,y,t-1} + ACCESS\_OCS_{r,d,y,t-1} \\ & \forall r,d,y,t \mid (r,y) \in RY', d \neq OTHER, t \notin T', t \neq \text{"}Oct08\text{"} \end{aligned} \tag{4}$$

$$\begin{aligned} INVENT_{r,OTH,y,t} = {} & INVENT_{r,OTH,y,t-1} + PROM_{r,OTH,y,t} \\ & -PROM_{r+1,OTH,y,t} + \sum_{d \mid d \neq OTH} TRF_{r,d,y,t} \\ & + \sum_{d \mid d \neq OTH} PROMTRF_{r,d,y,t} - NLOSS_{r,OTH,y,t-1} \\ & -FLOSS_{r,OTH,y,t-1} - HYT_{r,OTH,y,t} \\ & +accessNA\_ROTC_{r,OTH,y,t-1} + ACCESS\_OCS_{r,d,y,t-1} \\ & \forall r,y,t \mid (r,y) \in RY', t \notin T', t \neq \text{"}Oct08\text{"} \end{aligned} \tag{5}$$

$$\begin{aligned}INVENT_{r,d,y,t} = {} & INVENT_{r,d,y-1,t-1} + PROM_{r,d,y,t} \\ & -PROM_{r+1,d,y,t} - PROMTRF_{r+1,d,y,t} \\ & -TRF_{r,d,y,t} - NLOSS_{r,d,y-1,t-1} \\ & -FLOSS_{r,d,y-1,t-1} - HYT_{r,d,y,t} \\ & +accessNA\_ROTC_{r,d,y-1,t-1} + ACCESS\_OCS_{r,d,y-1,t-1} \\ & \qquad \forall r,d,y,t \mid (r,y) \in RY', d \neq OTHER, t \in T'\end{aligned} \tag{6}$$

$$\begin{aligned}INVENT_{r,OTH,y,t} = {} & INVENT_{r,OTH,y-1,t-1} + PROM_{r,OTH,y,t} \\ & -PROM_{r+1,OTH,y,t} + \sum_{d \mid d \neq OTH} TRF_{r,d,y,t} \\ & + \sum_{d \mid d \neq OTH} PROMTRF_{r,d,y,t} - NLOSS_{r,OTH,y-1,t-1} \\ & -FLOSS_{r,OTH,y-1,t-1} - HYT_{r,OTH,y,t} \\ & +accessNA\_ROTC_{r,OTH,y-1,t-1} + ACCESS\_OCS_{r,d,y-1,t-1} \\ & \qquad \forall r,y,t \mid (r,y) \in RY', t \in T'\end{aligned} \tag{7}$$

Fill and Requirements Constraints:

$$\sum_{y \mid (r,y) \in RY'} INVENT_{r,d,y,t} = \sum_{r' \mid (r,r') \in RR^F} \sum_{j \mid (d,j) \in DJ} FILL_{r,r',d,j,t} \qquad \forall r,d,t \tag{8}$$

$$\begin{aligned}req_{r,j,t} = {} & \sum_{r' \mid (r',r) \in RR^F} \sum_{j \mid (d,j) \in DJ} FILL_{r',r,d,j,t} \\ & +DEFICIT_{r,j,t} - SURPLUS_{r,j,t} \qquad \forall r,j,t\end{aligned} \tag{9}$$

$$\sum_{j \mid (d,j) \in DJ} FILL_{r,r,d,j,t} \geq \beta_{r,d} \sum_{y \mid (r,y) \in RY} INVENT_{r,d,y,t} \qquad \forall r,d,t \tag{10}$$

$$\eta_{r,j} req_{r,j,t} \geq Deficit_{r,j,t} \qquad \forall r,j,t \tag{11}$$

Loss Constraints:

$$NLOSS_{r,d,y,t} = \alpha_{d,y} INVENT_{r,d,y,t} \qquad \forall r,d,y,t \mid (r,y) \in RY' \tag{12}$$

Budget Constraints:

$$BUDGET_f \geq \sum_{r,d,y,t \mid (r,y) \in RY', (f,t) \in FT} cost_{r,y,t} INVENT_{r,d,y,t} \qquad \forall f \tag{13}$$

Accessions Constraints:

$$(min\_OCS)\, accessOCS_{r,d,y,t} \leq ACCESS\_OCS_{r,d,y,t} \leq (max\_OCS)\, accessOCS_{r,d,y,t} \quad \forall r,d,y,t \qquad (14)$$

Exclusions:

$$INVENT_{r,d,y,t} = 0 \qquad \forall r,d,y,t \mid (r,y) \notin RY \qquad (15)$$

$$HYT_{r,d,y,t} = 0 \qquad \forall r,d,y,t \mid (r,y) \notin RY^{H} \qquad (16)$$

$$PROM_{r,d,y,t} = 0 \qquad \forall r,d,y,t \mid (r,y) \notin RY^{P} \qquad (17)$$

$$PROMTRF_{r,d,y,t} = 0 \qquad \forall r,d,y,t \mid (r,y) \notin RY^{P} \qquad (18)$$

3. Formulation Description

The RCMOP's objective function (2) seeks to minimize the total gap index associated with the differences between inventory and work requirement throughout the planning period. The weight factors (w_j) allow planners to assign larger penalties to job fields that require full manning, and lower values to job areas which, if unfilled, would result in a lesser impact on the Navy's ability to execute its missions and the overall Maritime Strategy. In order to normalize the objective function to output an index in the interval [0, 1], and to account for the importance and size of the different work requirements, it is necessary to adjust the weights.

Normalized weights $\tilde{w}_{r,j,t}$ are defined in (1) to prevent smaller communities from having unreasonable control over the model's output. For example, if a very important (high weight) community has only four requirements and two are unfilled, its 50% gap would have a much greater impact on the objective function than would a low importance (low weight) community that had 1,000 requirements and only 500 filled (also a 50% gap). The resulting objective function (2) is a relative gap index. If all work requirements are filled (i.e., all deficit variables are zero), then the gap index vanishes. Conversely, if every work requirement were unfilled (all requirements are met,) then the index would become one. Therefore, minimizing the gap index should result in output variables that fill as many work requirements as possible by accounting for both the importance of the requirement itself and its relative size compared to the other requirements.

After initializing the first month (October 08) to the initial input inventory in (3), a series of balance equations (4-7) maintain the flow of personnel between ranks and designators over time. Specifically, when officers in designators except *OTHER* move through time (without advancing a YCS), they can be promoted into or out of rank *r*, transferred into designator *OTHER*, lost through natural or forced loss, or become HYT, as shown in (4). Figure 1 from this chapter illustrates the flows represented in constraint (4). For officers in designator *OTHER*, the balance of flow (5) is similar except that the equation must account for the incoming officers transferred from *SWO, SUB, SPEC, and AVIAT.* The structure in constraints (4-5) is repeated, though accounting for months when advancement in YCS occur (6-7).

Constraints (8-9) make use of *FILL* variables to meet work requirements in allowed ranks and job fields. *DEFICIT* and *SURPLUS* variables are used to account for overages and shortfalls. Constraint (10) bounds the fraction of officer inventory from a given rank and designator that can fill work requirements above or below their actual rank. Also, in order to keep all communities viable, the deficit for each rank r and work requirement j is set to a fraction of the total requirement by constraint (11).

Monthly natural loss figures are determined in Equation (12).

Constraint (13) ensures the manpower expenditures in each FY are within the given budget.

Constraints in (14) limit OCS accessions to lie within a specified range (upper and lower bounds) of the planned OCS accessions.

Finally, (15-18) are logical constraints to fix certain variables to zero so unauthorized pairings are avoided.

IV. RESULTS

This chapter presents our test scenario and associated computational results. The scenario is built using informed data, mostly drawn from sources within the N1 organization. Nonetheless, we caution the reader that our testing has been designed to verify the RCMOP's functionality and potential as a planning tool. The claims we make when describing our results later in this chapter are for that intention and not to prescribe any specific action. Specifically, we note that: (a) RCOMP is an approximating model, where some capabilities are represented in aggregated mode, otherwise simplified or simply omitted; (b) Some of the input data, such as weights, bounds on the percentage of officers filling out-of-rank jobs, loss rates, etc. are either estimated or subjectively interpreted by the author; and, (c) Prescription on specific actions would require a more detailed study about actual Navy leadership's intent.

A. SCENARIO DATA

1. Accessions

The monthly accession data, $access\_OCS_{rdyt}$ and $accessNA\_RTOC_{rdyt}$, has been drawn directly from the strength planning notice provided to all of the accession sources for FY-08 (CNP 2007). The sources considered are USNA, NROTC, and direct accessions through OCS that come both from the Navy's Recruiting Command as well as the Seaman to Admiral-21 program. Estimated accesion values for each source are based on current and projected inventories and have the form of (minimum, maximum) ranges for each designator. We use the midpoint of the range as the point estimate input for RCMOP. In addition, it is presumed that all USNA and NROTC accessions occur in May so they correspond to college graduation, and the OCS accessions occur evenly throughout the fiscal year.

	Projected OCS Accessions					Projected USNA/NROTC Accessions				
Month	**SWO**	**SUB**	**SPEC**	**AVIAT**	**OTHER**	**SWO**	**SUB**	**SPEC**	**AVIAT**	**OTHER**
OCT08	24	12	2	33	25	0	0	0	0	0
NOV08	24	12	2	33	25	0	0	0	0	0
DEC08	24	12	2	33	25	0	0	0	0	0
JAN09	24	12	2	33	25	0	0	0	0	0
FEB09	24	12	2	33	25	0	0	0	0	0
MAR09	24	12	2	33	25	0	0	0	0	0
APR09	24	12	2	33	25	0	0	0	0	0
MAY09	24	12	2	33	25	554	259	77	617	41
JUN09	24	12	2	33	25	0	0	0	0	0
JUL09	24	12	2	33	25	0	0	0	0	0
AUG09	24	12	2	33	25	0	0	0	0	0
SEP09	24	12	2	33	25	0	0	0	0	0
OCT09	25	17	2	37	26	0	0	0	0	0
NOV09	25	17	2	37	26	0	0	0	0	0
DEC09	25	17	2	37	26	0	0	0	0	0
JAN10	25	17	2	37	26	0	0	0	0	0
FEB10	25	17	2	37	26	0	0	0	0	0
MAR10	25	17	2	37	26	0	0	0	0	0
APR10	25	17	2	37	26	0	0	0	0	0
MAY10	25	17	2	37	26	545	265	78	623	46
JUN10	25	17	2	37	26	0	0	0	0	0
JUL10	25	17	2	37	26	0	0	0	0	0
AUG10	25	17	2	37	26	0	0	0	0	0
SEP10	25	17	2	37	26	0	0	0	0	0

Table 5. Monthly (projected) accessions by source and designator. Each accession enters service as an O-1 with zero YCS in a given month and designator.

Also, as discussed in the formulation presented in Chapter III.B, we assume USNA and NROTC accessions are known data, but let OCS accessions be optimized within *min_OCS* = 50% and *max_OCS* = 125% of its nominal point estimate, $access\_OCS_{rdyt}$. Table 5 provides the accessions values used in our scenario.

2. Natural Loss Rates

The loss rates, α_{dy}, have been drawn from the Officer Personnel Information System Data Mart (OPIS) via the Highlander on-line interface (Peak Software, Inc. , 2009). Specifically, we have included the following natural loss categories in the query: "Retirement - Nonconventional inability to perform," "Retirement – Normal," "Resignation", "Discharge - Involuntary or Admiralty," and "Miscellaneous Losses."

In order to both capture recent trends while also using a sufficient amount of historical data, we have derived our loss rates using historical rates from FY-06 though FY-08 (the last year existent in the database). The rates aggregate over ranks because of database inaccuracies that may arise from the miscalculation of loss due to promotion (loss to specific rank, but not a Navy strength loss). Thus, the available data presume that an O-3 with ten YCS will have the same loss rate as an O-4 with the same YCS, while conventional wisdom would tell us this may not be the case.

YCS	SWO	SUB	SPEC	AVIAT	OTHER
0	1.20%	0.70%	1.80%	5.90%	1.20%
1	2.50%	1.60%	2.20%	3.10%	1.40%
2	2.60%	1.70%	1.20%	1.60%	1.30%
3	7.40%	1.60%	1.50%	1.60%	5.80%
4	10.90%	11.40%	1.80%	6.10%	8.30%
5	12.70%	14.40%	0.70%	4.60%	5.40%
6	13.80%	20.10%	1.30%	4.50%	4.50%
7	4.40%	15.60%	8.70%	6.30%	5.50%
8	3.90%	5.20%	17.70%	5.60%	5.10%
9	6.10%	5.10%	12.30%	12.60%	10.90%
10	7.90%	6.60%	11.40%	7.00%	8.30%
11	7.20%	6.90%	4.90%	13.10%	7.70%
12	4.80%	6.90%	3.10%	2.70%	6.90%
13	2.70%	3.20%	3.70%	2.60%	5.10%
14	1.60%	3.60%	2.00%	1.40%	3.10%
15	2.90%	4.80%	2.70%	0.00%	4.80%
16	1.40%	2.20%	2.20%	2.60%	2.90%
17	3.00%	7.40%	4.00%	0.00%	4.60%
18	6.10%	7.50%	7.40%	4.60%	10.00%
19	23.80%	19.20%	29.60%	28.80%	29.70%
20	11.10%	6.50%	12.30%	13.00%	15.40%
21	11.00%	9.80%	12.10%	5.10%	9.90%
22	9.10%	9.90%	12.00%	7.90%	13.00%
23	11.20%	7.80%	11.20%	8.10%	18.20%
24	13.00%	10.90%	15.30%	20.00%	22.60%
25	19.90%	17.50%	24.70%	28.10%	23.40%
26	21.90%	23.10%	22.90%	20.00%	25.80%
27	24.50%	9.70%	26.10%	18.20%	27.50%
28	29.40%	32.60%	31.90%	23.10%	32.10%
29	29.60%	25.00%	46.60%	63.60%	62.00%
30	22.20%	50.00%	25.00%	0.00%	0.00%

Table 6. Estimates of yearly natural loss rates by YCS and designator.

Given an annual loss rate R, we use the formula $r = 1 - (1 - R)^{1/12}$ to derive a monthly rate, *r*, as required by our RCMOP model.

Table 6 shows the annual loss rates by YCS and designator.

3. Cost and Budget Data

The monthly cost of each officer by rank and YCS, $cost_{ryt}$, is derived from a combination of the calendar-year 2008 pay tables and summary data provided by the N1-SRB of overall 2008 manpower categorical expenditures. These total expenditures are compared with the total man-years of work performed within each classification of officer to derive monthly per-officer costs. The monthly cost is then inflated using the Naval Center for Cost Analysis (NCCA 2008) Inflation Calculator for FY-09.

Similarly, the budgets for FY-09 and FY-10, $budget_f$, are derived from the FY-11 programming rates as published in the PR-11 manpower programming rates memorandum (Ferguson 2008). These rates, which describe the cost that the U.S. Congress authorizes to the Navy for each officer requirement of a specific rank, are deflated to calculate FY-09 and FY-10 values and then multiplied by annual requirements to arrive at the budgets for each fiscal year. The Appendix shows the 2008 monthly officer cost data with inflation indices as well as the programming rates for FY-09 through FY-11 with the resulting budget calculations.

The final budgets for the O-1 through O-6 work requirements and the designators modeled are \$3.89 billion and \$3.99 billion for FY-09 and FY-10, respectively.

4. Initial Inventory and Requirements

The initial inventory values, $invent0_{rdy}$, have been derived from the actual officer inventory as recorded in the Total Force Manpower Management System (TFMMS), the authoritative database used by the Navy to track all personnel and billets (CNO 2007), on October 1, 2008. Similarly, TFMMS has been used to retrieve work requirements, req_{rjt}, for FY-09, FY-10, and FY-11. Since these data are only available by FY, our model derives monthly requirements by linearly interpolating requirements for two consecutive FYs. Note that, if we assumed constant requirements throughout each FY, an unrealistic "mass exodus" of officers would occur each September to match the next FY's requirements.

5. Weights and Other Parameters

The percentage of officers allowed to fill out-of-current-rank work requirements is limited at 5% for all ranks and designators (i.e., β_{rd}=0.95). In addition, no constraint is levied on the deficit as a fraction of work requirement for a given rank and job field (i.e., η_{rd}=1.00).

The priority weights used (w_j) are shown in Table 7. Since the Submarine and Special Warfare communities involve arduous and potential life-threatening duties, gaps in those requirements have been given highest priority. Conversely, OTHER and 1000-coded billets, which involve primarily staff and fleet-support roles, are given the lowest priority.

It is important to note that these weight values are for testing purposes only, and neither represent any specific guidance from Navy leadership nor are they tied to any specific source of data.

Work Requirement	Weight
jSWO	75
jSUB	100
jSPEC	100
jAVIAT	75
jOTHER	50
j1000	25

Table 7. Gap weights by work requirement.

B. RESULTS

In this section we describe the results produced by the RCMOP model for the scenario described in Section A.

In order to focus on the most important results, sometimes we restrict our discussion to the two largest communities, SWO and SUB, which are also known for having difficulties retaining mid-grade officers.

We solve RCMOP on a personal laptop at 1.6 GHz with four Gb of RAM, running under Windows Vista. We implement and generate the model using the General Algebraic Modeling Language (GAMS Development Corporation 2008), and solve it using the XA solver (GAMS/XA, 1994). This implementation of the RCMOP consists of over 44,263 variables and 15,798 equations, with a computational time for an optimal solution of approximately two minutes.

1. Gap Index

The overall gap index for our scenario is 0.0662 (6.62%). This figure should not be interpreted as 93.34% of billets being filled, but rather as an overall billet filling efficiency of 93.34%, given the job priorities. Remark: The actual (non-weighed) percentage of billets being filled is 92.9%. Also, for comparison purposes, when the RCMOP is run using only the current inventory and zero accessions or losses, the resulting gap index is more than double at 14.2%.

2. Inventory and Requirements

Figure 2 shows the monthly inventory and work requirement (aggregated for all ranks, designators and work fields) as a function of time. It is apparent that the "readiness-gap" between required work and the available officer workforce decreases over the two-year horizon as the optimized inventory seeks to match the work requirements. The saw-toothed shape of the inventory is due to two main reasons: (a) the large influx of new officers that occurs each May due to USNA and NROTC college graduations and subsequent officer commissioning, and (b) losses that occur throughout the year.

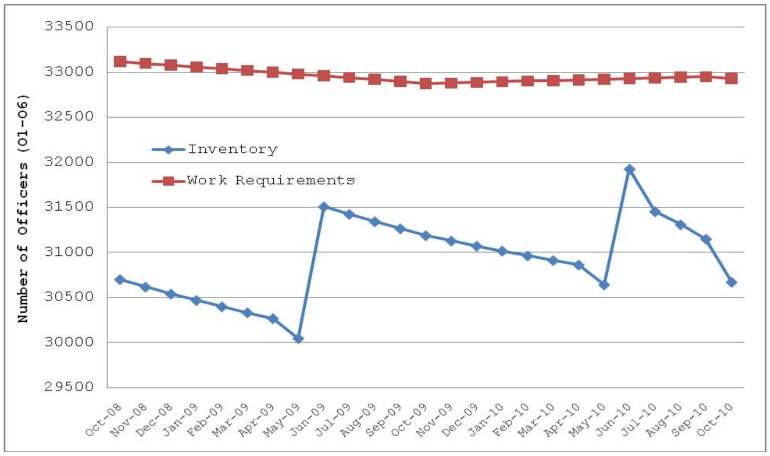

Figure 2. Monthly total inventory and requirements.

Figure 3 shows total balance-of-flow accounting for all strength gains and losses to the system over the two years of the study.

	30,704	Starting Inventory
-	4,690	Natural Losses
-	1,026	Forced Losses
-	123	HYT Losses
+	3,105	USNA/ROTC Accessions
+	2,703	OCS Accessions
	30,674	Final Inventory

Figure 3. Total flow balance confirmation calculation

As we can see in Figure 4, for the SWO community, the total initial inventory exceeds the work requirements throughout the period of study. This is due to over-accessing at the lower ranks, which planners usually accept in order to compensate for the difficulty in retention to the Department-Head level (Mackin and Darling 1996). This is true also in the Aviation and Submarine communities. Eventually, however, the solution exhibits inventories closer to the requirements, where possible. In the case of

the SPEC community, RCMOP is unable to satisfy the requirement, even by forcing to zero any use of SPEC officers to fill 1000-coded billets.

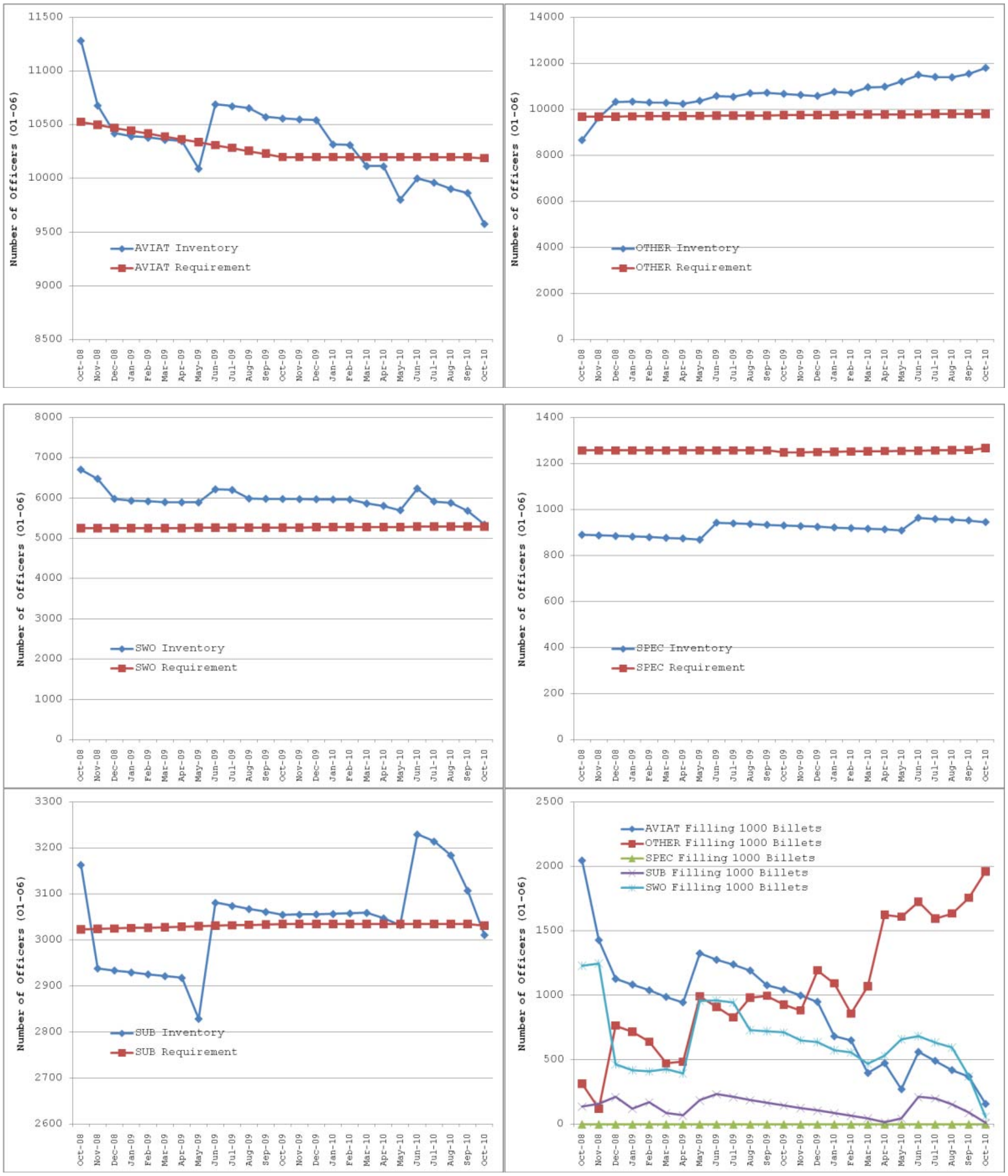

Figure 4. Inventory, requirements, and 1000-coded billets by designator and month.

As would be expected, the officer job community with the lowest priority weighting (OTHER) is increasingly used to fill the 1000-coded billet requirement as time advances, and the higher-priority designators fill a smaller fraction of those requirements.

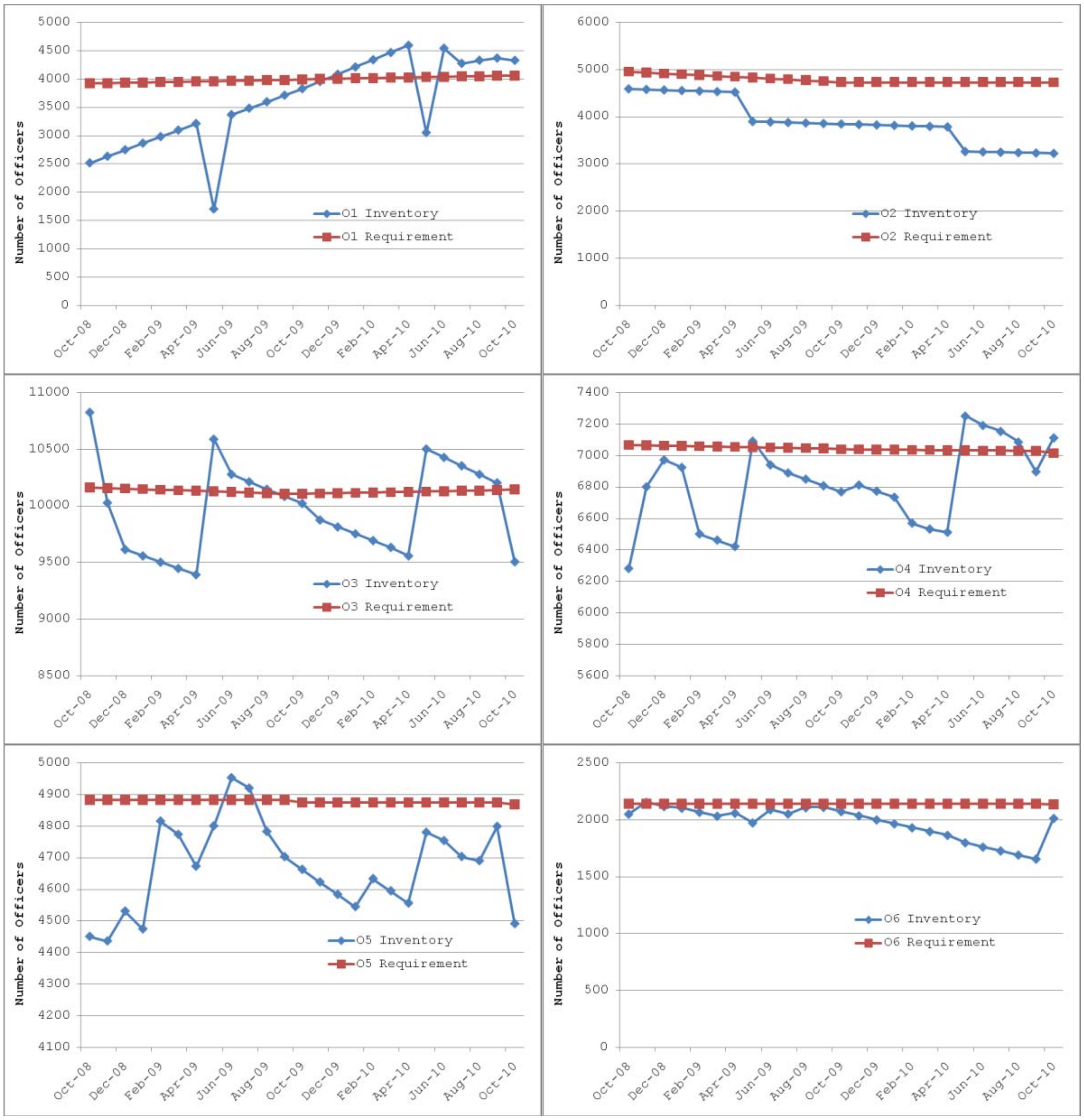

Figure 5. Total officer inventories and requirements for each rank by month.

Looking at the total inventory and requirements for each rank (Figure 5), the variability in the O-3 and O-4 population becomes evident, representative of the significant loss that occurs during those years of service. Within the last six months of the horizon, the O-4 inventory begins to consistently meet (and sometimes exceed) its requirements for all designators.

For the SWO and SUB communities (Figure 6), both have excess strength at the O-3 level. For O-4's, the SWO community remains over strength throughout the model's time horizon, whereas the SUB community's O-3 population correctly accounts for loss and promotion expectations to create a more stable O-4 population.

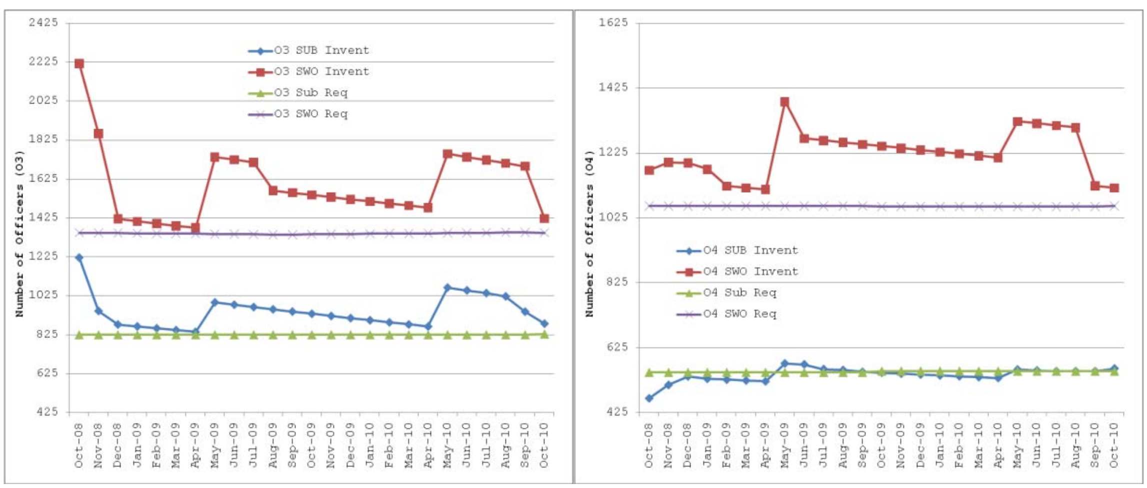

Figure 6. O-3 and O-4 inventory and requirements for the Surface Warfare and Submarine communities

As both of these communities had excess strength in the lower ranks at the beginning of the planning horizon, the model compensates for these inventory surpluses by utilizing the *FLOSS* decision variables to correct for down-stream excess strength situations (Table 8). The SWO community starts with too many officers in the O-1 to O-3 range compared to the down-stream demand, forcing the loss of over 500 O-1s and O-3s during the two years modeled, while the SUB community sheds 53 O-1s.

RANK	SWO	SUB	SWO	SUB
O-1	294	53		
O-3			243	0

Table 8. Forced losses for SUB and SWO officers totaled over FY-09 and FY-10.

Although in RCMOP there are no costs or penalties associated with forced losses, in reality these incur costs to the Navy in the form of severance packages and unrealized education and training expenses, among others. These expenditures are not paid from the same account built from the programming rates utilized to calculate the budget used by RCMOP. Future research should devise a separate budget to limit forced losses, along with any other applicable constraints.

3. Cost and Budget

The total cost, as represented by the left-hand-side of our budget constraint (13) results in \$3.502 billion for FY-09 and \$3.614 billion for FY-10. These figures represent a cost savings of over \$385 million in FY-09 and \$376 million in FY-10 when compared to the programmed amounts used in the model. While these cost savings appear attractive, we believe that this only reflects a preliminary validation for RCMOP being within 10% of each budget estimate.

4. Promotions

For the purposes of this model, promotions are bounded by the YCS required for advancement, as dictated by Navy policy and U.S. Code, Title 10. The promotion rates themselves, which are also limited by law and policy, have been intentionally left unbounded and instead determined by the need to fill requirements.

Interestingly, the total promotion rates by rank and year (calculated with respect to the beginning officer inventory in the YCS band for promotions) are similar to the required bands (recall Table 4 in Chapter III), with a few exceptions (see Table 9).

FY09 PROMOTIONS					
To rank:	**O-2**	**O-3**	**O-4**	**O-5**	**O-6**
Promoted	1,624	2,231	2,295	1,260	511
Eligible	1,644	2,289	2,773	1,307	1,008
Rate	98.8%	97.5%	82.7%	96.4%	50.7%
AVG YCS			9.05	15.35	21.98
FY10 PROMOTIONS					
To rank:	**O-2**	**O-3**	**O-4**	**O-5**	**O-6**
Promoted	1,668	2,176	1,663	764	415
Eligible	1,688	2,232	2,051	1,053	1,036
Rate	98.8%	97.5%	81.1%	72.5%	40.0%
AVG YCS			9.02	15.00	21.03

Table 9. Total promotions for FY-09 and FY-10

In both years, we see nearly 100% promotion to O-2 and O-3, as expected. Also, promotion to O-4 is within the 70-90% window and promotion to O-6 is within the 40-60% band. For FY-09, promotion to O-5 appears unusually large (96%), but returns to the normal 60-80% range in FY-10. In addition, the solution chooses to promote to O-4, O-5 and O-6 early in the allowable band for YCS (9-11, 15-17, and 21-23 respectively) with the exception of FY09 O-6 promotions at about 22 YCS. This represents another validation of the RCMOP model with respect to current planning practice, while providing additional insights into select promotion rate adjustments.

5. Billet Filling

Our *FILL* decision variables describe how how the officer inventory is matched up with the requirements, both with the allowed rank (using the one-up/one-down rule) and within the proper community (all designators within their own job fields and 1000-coded billets). Figure 7 shows this output by rank.

RCMOP utilizes the available 5% to fill one-up, one-down requirements differently by rank and month. Specifically, O-2s tend to be used to fill one-down early in the modeling horizon, but shift to one-up fills later. O-3s and O-4s tend to be used for both one-up and one-down evenly for the entire time period, although the last six months seem to show the O-3s trending down to O-2 and the O-4s trending up to O-5. This is consistent with the results shown previously in Table 6, where it is apparent that during the last six months, there are O-2 and O-5 inventory deficits, while the O-3 and O-4 populations have surplus populations (compared to their respective work requirements).

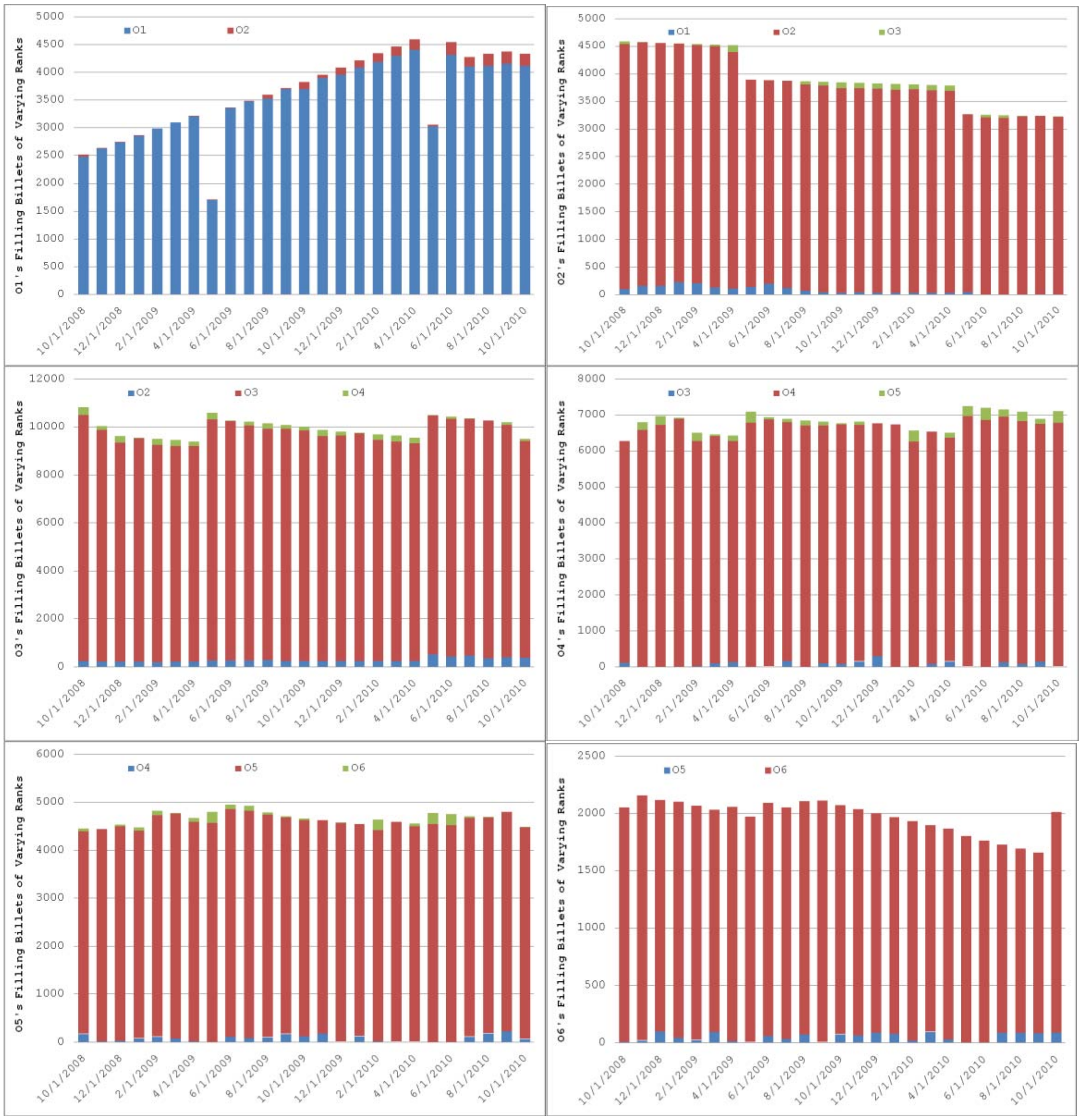

Figure 7. Total officers filling work requirements at, above, and below their current pay grade for each rank.

With respect to filling j1000 work requirements, the solution makes significant changes over time regarding how the communities fill those billets (see Figure 8). At the beginning, more than 80% of the 1000-coded work requirements are filled with the AVIAT and SWO inventories. By the end of FY-10, nearly 90% are filled by the OTHER category alone (which had filled less than 10% at the start of FY-09).

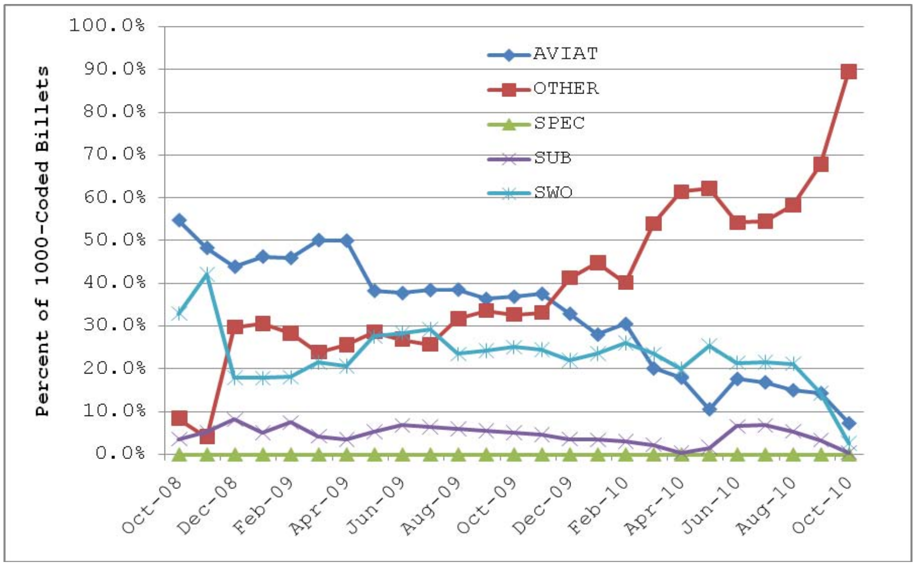

Figure 8. Percentage of 1000-coded work requirements filled by various community inventories.

Similarly, Figure 9 shows the variation in j1000 fills as a percentage of total community inventories for each designator and month. Close to 20% of each of the AVIAT and SWO community's strength is used to fill j1000 jobs in Oct-08, compared to around 2% in Oct-10. Conversely, the OTHER communty's load increases from 4% to over 16% of total strength utilized for the j1000 billets.

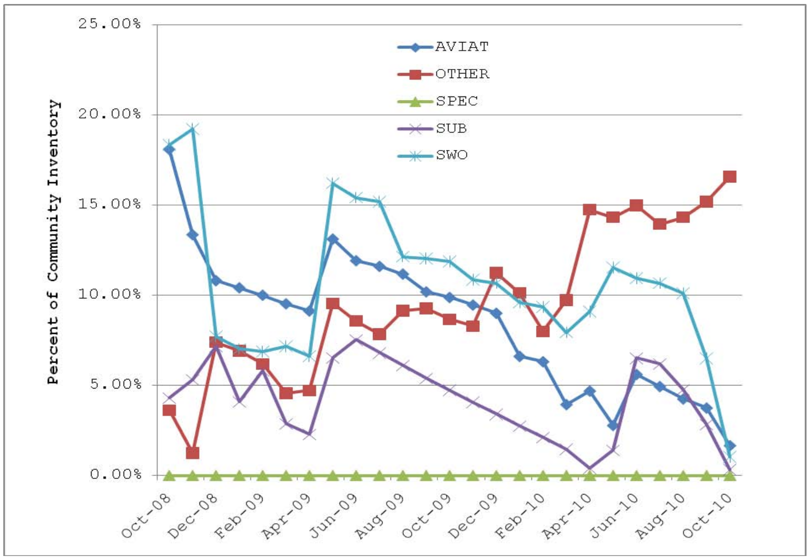

Figure 9. Percentage of total community inventories used to fill j1000 work requirements

There are two main reasons for this behavior in our optimal solution. First, the weights established in this scenario will tend to minimize the warfare-specific strength deficits. Thus the RCMOP model finds it beneficial to use SPEC, SUB, SWO and AVIAT officers to fill work requirements within their own fields, and is willing to leave OTHER requirements with a larger gap to ensure the j1000 fields are adequately staffed.

Second, the j1000 work requirement itself is the sum of 1000 and 1050-coded billets. In reality, 1000-coded billets can be filled by any officer, but 1050 billets require a warfare-qualified officer. Had the model been more specific is in its treatment of the j1000 billets (as well as the weighted risk associated with filling the 1000 billets versus the 1050 billets) it is likely that more warfare officers and fewer staff and/or support offers would have been utilized.

6. Transfers

Since RCMOP only allows designator transfers into the OTHER community, it is expected that warfare communities with excess inventory will transfer personnel to OTHER, when available. In turn, these extra personnel are utilized to fill both jOTHER and j1000 work requirements. Table 10 shows a breakdown of transfers in our optimal solution.

Rank	AVIAT	SPEC	SUB	SWO	Total
O-1	344	20	41	308	713
O-2	0	0	0	71	71
O-3	49	0	330	683	1,062
O-4	1,005	4	41	292	1,342
O-5	923	0	48	279	1,250
O-6	231	0	13	83	327
Total	2,552	24	472	1,716	4,764

Table 10. Inventory transfers from each community into the OTHER community, by rank, for FY-09 and FY-10 combined.

Although the jAVIAT requirements carry greater weight than the jOTHER and j1000 ones, the solution still chooses to move more than 2,500 officers out of AVIAT and into OTHER, with especially large numbers in the O-4 through O-6 ranks. This is indicative of the relatively small gap that exists in the upper ranks of the AVIAT community when compared to the other communities and work requirements. This result may be especially sensitive to the method by which the objective function prioritizes gaps, and particularly to the choice of weights.

7. OCS Accessions

The result increases the total OCS accessions to 111% of their initial projections (see Table 11).

Designator	Projected	RCMOP	% of Projected Value
AVIAT	840	939	112%
OTHER	612	668	109%
SPEC	48	59	122%
SUB	348	371	107%
SWO	588	667	113%
Totals	2,436	2,703	111%

Table 11. OCS accessions by designator, with baseline projected, RCMOP recommendations, and percentage of projected values.

The SPEC community demands the greatest increase in new O-1s at 122% of projected values, which is consistent with both the greater weight assigned to the jSPEC requirements and the consistency with which the SPEC inventory is below its requirements. While previous findings have been largely dependant on the choice of requirement weights and assumptions regarding the categorization of designators and job-fields, this result is mainly dependent on the reliability of the total loss-rates assumed by RCMOP, and the accession source's ability to compensate for those strength losses.

One can conclude that, at a minimum, Navy strength planners should increase accessions in order to match requirements, although this result is largely expected due to the aforementioned presumption that overall inventories can not match overall requirements.

8. Deficit and Weighted Gap Analysis

Since the model's intention is to minimize the gaps between inventory and requirements, it is expected that the total number of deficits should decrease over the time horizon, as well as shift from the communities with lower weights to higher-weighted communities. This occurs, to a degree, as shown in Figure 10.

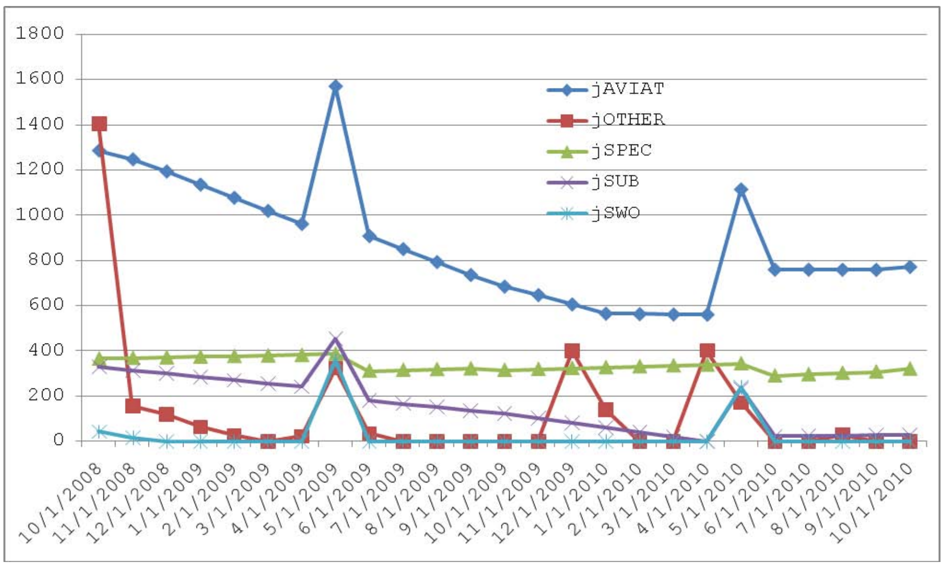

Figure 10. Billet filling deficits by requirement (except j1000)

While all of the deficits decrease with respect to time, we would expect that the jSPEC deficit would decrease more than it does, since it shares the highest-weighted work requirement (w_j=100) with that of the jSUB requirement. Figure 11 looks more closely at the change in the SUB and SPEC deficits with respect to time.

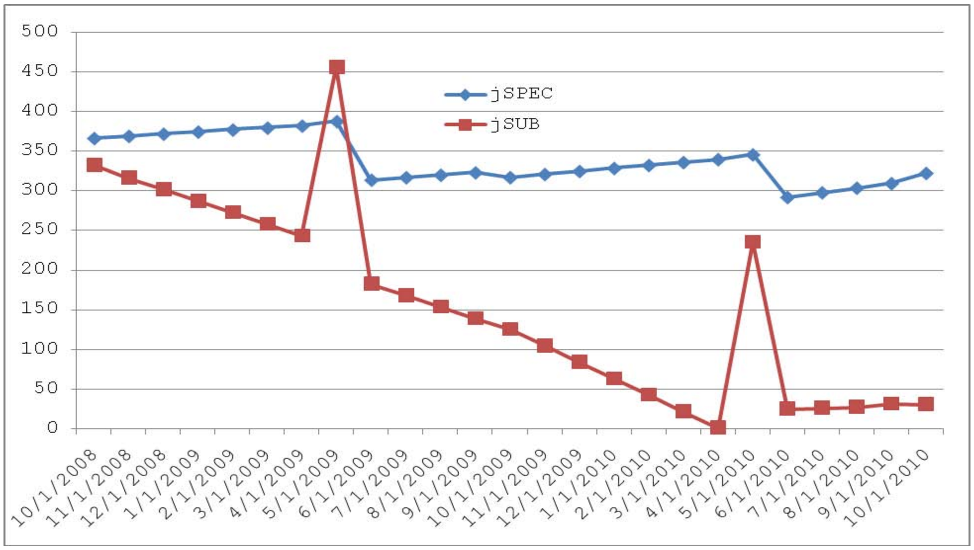

Figure 11. jSPEC and jSUB billet filling deficits over time.

This outcome is likely explained by the nature of the objective function. The model is built to minimize the normalized weighted gap, which is dependent on both the weight (relative to the type of requirement) and the requirement size. Despite the fact that the jSPEC weight is the highest at 100, its work requirement is so small relative to the other communities that it makes its normalized weight the second smallest (see Table 12). (Recall that the weights used in this scenario are solely designed to test the RCMOP's functionality.)

Req	**Adjusted Weight**
j1000	0.00001
jAVIAT	0.00192
jOTHER	0.00076
jSPEC	0.00028
jSUB	0.00121
jSWO	0.00124

Table 12. Normalized weight values for October 08, O-1 work requirements.

While the observation of the unexpected behavior of the weights does not diminish the proof-of-concept of the RCMOP as a useful tool for manpower and budget planners, it does highlight the importance of carefully choosing the weights for use in a realistic planning environment.

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V. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The RCMOP has shown the potential to provide manpower and budget planners with insights on sizing and shaping the force to minimize the impact of shortages while ensuring compliance with fiscal constraints. While some findings from the RCMOP model's initial scenario may be applied to current planning, most of the conclusions focus on ways to improve the model for future specification and use.

A. SIGNIFICANT FINDINGS

1. Increase OCS Accessions

Based on the total inventory, planned accessions and approximated loss rates, the RCMOP recommends an 11% increase in OCS accessions to better meet requirements. While the breakdown of how requirements are met (by community and month) is subject to change based on initial inputs like gap weights and community and job subcategory assumptions, the recommended overall increase in accessions may be feasible.

2. Filling 1000-Coded Billets

RCMOP clearly illustrates that an increase in the fraction of 1000- and 1050-coded billets filled by staff and support personnel would decrease the readiness gap associated with the warfare communities. The specific scope and size of this shift with regard to ranks and communities, however, would require further investigation and better specification of initial modeling assumptions.

3. Validations

In both the cost values and promotion metrics, the RCMOP provides results consistent with those estimated by planners and dictated by law. By letting RCMOP freely decide optimal values for these variables, we have also provided insights into the direction that manpower planners might take to improve their decisions and projections.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

1. Weights and Objective Function

The RCMOP model output depends on the weights assigned to identified gaps, and the objective function itself. Primarily, the weights must be well-researched and consistent with the intent of Navy leadership. For the objective function, we find that the product of the weight and requirements ratio does not always provide a normalized weight that is consistent with the original intent. However, whenever subjective weights are employed to account for multiple goals, it is important to explore the efficient frontier of the problem.

Also, rather then the current weighting scheme which is only dependent on the requirement field, additional gap terms should be added. These terms include officers filling ranks above and below their current rank, filling billets of each specific type available, and the various officer types that can fill 1000- and 1050-coded billets.

Further research is also needed to look at alternative objective functions, such as piecewise linear functions that vary the weights based on absolute gap size. That is, the penalty term should account for the varying importance of gaps in different grades within the same job fields.

A complementary approach would consist of using cost directly in the objective function. The cost function would attempt, for example, to minimize the monetary risk of manning shortfalls, which could be handled by community and rank as individual constraints.

2. Inventory Data

RCMOP assumes no prior service personnel exist in the inventory and that advancement of YCS occurs only once throughout the year. While this simplifies the model formulation and the amount of data input required, more detail should be added to capture the inventory with greater specificity. Dimensions should be added to: (a) Track the officer commissioning months, so that YCS can be advanced each month on the modeling horizon rather than in a unique month for all officers; and, (b) Account for actual YOS to capture the significant percentage of prior-service officers within the population.

3. Designators and Billets

The current subgroups of designators and billets are simplified ones and do not describe the officer population accurately. In addition to more designators, subspecialty codes can also be added to the inventory and billets to better track the needs of the Navy and how well our officer inventory can fill the necessary competencies.

4. "Transfer" and "Fill" Variables

With greater detail incorporated into the inventory and billet base, the transfer and fill variables can be enhanced to incorporate more realistic movement between communities, billets and subspecialty areas. For example, recommendations can be made by the model for the number of operations research analysts (subspecialty code 3211) needed in a given month and year by the fleet, which can then be used to drive the demand for school seats at the Naval Postgraduate School.

5. Interface with Simulation Output for Loss Rates

The quality of any model is based on its inputs, and stochastic values that vary from year to year can quickly degrade the quality of the output. By using computer simulation to estimate the range of possible future loss rates, for example, we could allow our result to better mirror the volatility in inventory and requirement gaps (Schirmer et al., 2006).

APPENDIX

This appendix describes the process followed by the author to derive the monetary values used as input data for the RCMOP model. Cost and budget terms have been calculated by using known data for certain time periods and then applying predicted inflation indices to equate them in value for comparison purposes.

A. MONTHLY OFFICER COSTS

For the monthly officer costs, the 2008 pay tables (Defense Finance and Accounting Service, 2008) have been combined with estimates for the housing, Basic Allowance for Subsistence (BAS), Federal Insurance Contributions Act (FICA) and retirement accrual costs to create a total 2008 monthly officer rate.

The average monthly housing cost is calculated by: (a) taking the Navy's total housing expenditures, which include both the Basic Allowance for Housing (BAH) and the Overseas Housing Allowance (OHA) for each rank and service combination, (b) dividing this number by the total man-days that exist for each analogous rank-year combination, and (c) multiplying the result by 30.4 days/month.

The monthly subsistence rate of $202.76 has been used for BAS. The FICA rate is calculated by taking 7.65% of the first $100,200 expected annual salary, adding 1.45% of any expected earnings above $100,200, and dividing the result by 12 months.

Retirement accrual is set at 29% of base pay, and the unemployment compensation index (which is mentioned in the programming rate description described later) is assumed to be zero based on historical data (FY-09 Budget Estimates 2008).

Once these cost categories are combined for a monthly total per officer (by rank and YCS), the total 2008 cost is inflated for use in 2009 and 2010 using manpower-specific inflation indices of 3.39% and 6.86% (compound), respectively (NCCA 2008). Table 13 shows these figures, already adjusted for inflation.

		Inflation Index:	1.0339	1.0686
Rank	**YCS**	**2008**	**2009**	**2010**
O-1	**0**	$ 5,041.73	$ 5,212.59	$ 5,387.41
O-1	**1**	$ 4,990.24	$ 5,159.35	$ 5,332.38
O-1	**2**	$ 5,358.80	$ 5,540.40	$ 5,726.21
O-2	**2**	$ 6,276.84	$ 6,489.55	$ 6,707.20
O-2	**3**	$ 7,009.95	$ 7,247.51	$ 7,490.58
O-2	**4**	$ 7,293.65	$ 7,540.82	$ 7,793.72
O-3	**4**	$ 8,179.75	$ 8,456.95	$ 8,740.58
O-3	**5**	$ 8,200.04	$ 8,477.93	$ 8,762.27
O-3	**6**	$ 8,476.84	$ 8,764.11	$ 9,058.04
O-3	**7**	$ 8,489.73	$ 8,777.44	$ 9,071.81
O-3	**8**	$ 8,841.16	$ 9,140.78	$ 9,447.34
O-3	**9**	$ 8,830.31	$ 9,129.56	$ 9,435.74
O-3	**10**	$ 9,119.77	$ 9,428.83	$ 9,745.05
O-3	**11**	$ 9,028.01	$ 9,333.95	$ 9,647.00
O-3	**12**	$ 9,493.59	$ 9,815.32	$10,144.50
O-4	**9**	$ 9,604.07	$ 9,929.54	$10,262.56
O-4	**10**	$10,138.60	$10,482.18	$10,833.73
O-4	**11**	$10,093.82	$10,435.89	$10,785.89
O-4	**12**	$10,493.11	$10,848.71	$11,212.56
O-4	**13**	$10,548.83	$10,906.31	$11,272.09
O-4	**14**	$10,892.94	$11,262.09	$11,639.80
O-4	**15**	$10,900.32	$11,269.71	$11,647.68
O-4	**16**	$11,030.29	$11,404.09	$11,786.56
O-4	**17**	$11,019.15	$11,392.58	$11,774.66
O-4	**18**	$11,101.27	$11,477.48	$11,862.41
O-4	**19**	$11,106.70	$11,483.10	$11,868.22
O-4	**20**	$10,796.65	$11,162.54	$11,536.91

Rank	YCS	2008	2009	2010
O-5	15	$11,464.74	$11,853.27	$12,250.80
O-5	16	$11,987.74	$12,393.99	$12,809.66
O-5	17	$12,004.75	$12,411.58	$12,827.84
O-5	18	$12,254.23	$12,669.51	$13,094.43
O-5	19	$12,258.22	$12,673.64	$13,098.69
O-5	20	$12,598.63	$13,025.59	$13,462.44
O-5	21	$12,587.11	$13,013.67	$13,450.12
O-5	22	$12,862.21	$13,298.10	$13,744.09
O-5	23	$12,930.58	$13,368.79	$13,817.15
O-5	24	$12,922.48	$13,360.41	$13,808.49
O-5	25	$12,938.57	$13,377.05	$13,825.69
O-5	26	$12,958.10	$13,397.23	$13,846.55
O-5	27	$12,873.80	$13,310.07	$13,756.47
O-5	28	$12,196.49	$12,609.81	$13,032.72
O-6	21	$14,097.60	$14,575.35	$15,064.18
O-6	22	$14,367.41	$14,854.31	$15,352.49
O-6	23	$14,357.57	$14,844.13	$15,341.97
O-6	24	$14,604.77	$15,099.71	$15,606.12
O-6	25	$14,588.50	$15,082.89	$15,588.74
O-6	26	$15,173.54	$15,687.75	$16,213.89
O-6	27	$15,199.64	$15,714.73	$16,241.78
O-6	28	$15,190.16	$15,704.93	$16,231.65
O-6	29	$15,362.60	$15,883.22	$16,415.91
O-6	30	$15,154.94	$15,668.52	$16,194.01

Table 13. Individual officer monthly costs by rank, YCS and calendar year.

B. TOTAL BUDGET

In order to calculate the budget allocated to the Navy for manpower resources, Congress prescribes programming rates for work requirements, which in turn determine the total dollar amount. The latest values were provided as part of the preparations for the Program Review 2011 (PR-11) occurring during 2009. These rates include values that, when multiplied by the work requirements used in the model, can create an estimated portion of the total budget that can be assigned to the manpower modeled in this thesis.

In order to transform the FY-11 values into FY-09 and FY-10 values, the rates have been deflated using inflation indices provided by NCAA (2008). Table 14 summarizes the results.

Rank	FY-09 Programming Rates	FY-09 Work Requirements	FY-10 Programming Rates	FY-10 Work Requirements
O-1	$68,979	3,925	$71,295	3,995
O-2	$88,477	4,951	$91,449	4,728
O-3	$109,380	10,160	$113,053	10,103
O-4	$131,686	7,065	$136,109	7,038
O-5	$153,003	4,883	$158,142	4,874
O-6	$182,147	2,138	$188,264	2,137
Budget:	$3,887,014,476		$3,990,421,637	

Table 14. Estimated programming rates and modeled budget amounts for FY-09 and FY-10.

The cost line items included in the programming rates include base pay, BAH/OHA and BAS, FICA, and retirement pay accrual (Ferguson 2008). These are the same cost terms used for the individual monthly terms described in the previous section, creating an analogous cost comparison.

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